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CENTRAL INTELLIGENCE AGENCY
INFORMATION FROM
FOREIGN DOCUMENTS OR RADIO BROADCASTS

REPORT
CD NO.

50X1-HUM

COUNTRY	USSR
SUBJECT	Scientific - Tungsten deposits
HOW PUBLISHED	Bimonthly periodical
WHERE PUBLISHED	Moscow
DATE PUBLISHED	March and April 1947
LANGUAGE	Russian

DATE OF INFORMATION 1947

DATE DIST. 20 Apr 1949

NO. OF PAGES 7

SUPPLEMENT TO REPORT NO.

THIS IS UNEVALUATED INFORMATION

SOURCE Tsvetnyye Metally, No 2, 1947. (FDB Per Abs 28T69 -- Translation requested.)

OCCURRENCE OF TUNGSTEN DEPOSITS IN USSR

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Tungsten is concentrated in industrial quantities in three different types of deposits, each varying in its mineralogical composition. These are: wolframite (Fe,Mn) WO_4, scheelite-quartz ($CaWO_4$ + SiO_2), scheelite-skarn ($CaWO_4$ + (Ca, Fe,Mg)mSiOn)

These formations, sharply distinguished from each other, are in places intermixed. This, however, does not nullify the general rule of separate occurrence of these deposits.

A. Wolframite Formation

Wolframite is the principal ore-bearing mineral. It varies in its composition from an almost clean manganese huebnerite (Dzhida) to an almost exclusively ferrous ferberite (Sherlova Mountain). Quartz is the basic mineral, constituting the ore body of the deposits of a wolframite formation. Feldspars and mica are present in an appreciably lesser quantity. Fluorite and topaz are fairly characteristic (Akchatau in Karaganda Oblast, Kazakhstan; Sherlova Mountain, Chita Oblast), and one sometimes meets beryl (Atasu in Karaganda Oblast, Kazakhstan; Belokurikha, Altay Kray).

Molybdenite and cassiterite, in addition to wolframite, are met in industrial quantities in the ore minerals of the deposits under consideration. The Chimdagotuy (Altay Kray) and the Akchatau, (Karaganda Oblast) deposits are wolframite-molybdenite; the Atasu, (Karaganda Oblast) and Verkhne-Ipatimskoye (Bureya, Amur Oblast) deposits are wolframite-cassiterite. Large deposits comprising three profitable components wolframite, molybdenite, and cassiterite are unknown, although molybdenite is sometimes found in wolframite-cassiterite deposits (Bichi, Lower Amur Oblast) and cassiterite in wolframite-molybdenite.

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Besides molybdenite, a bismuth glance (bleak) is sometimes noted (Belukha, Altay Kray), as is arsenopyrite (Ubinskoye, East Kazakhstan Oblast), and copper pyrite with sulfides of iron (Kol'yvan', Altay Kray).

Sulfides of lead and zinc are met only rarely (Boyevka, Sverdlovsk Oblast).

Among the characteristic ore minerals of wolframite formation, hematite, in the forms of micaceous iron ore (Degelin, Kazakhstan) should be mentioned.

B. Scheelite-Quartz Formation

The scheelite-quartz formation is characterized by the presence of gold, in addition to the two chief minerals, scheelite and quartz.

Sulfides are important here. Among them, arsenopyrite (Kti-Tiberda, Georgian SSR), and antimonite (Unglichikan, Amur Oblast; Kuludzhun, East Kazakhstan Oblast) are most frequently found, although sulfides of iron, copper, zinc and lead are also common.

Cassiterite is found in quantities of practical interest in a few of the scheelite-quartz formations (Khatyanakh, Kol'yma Basin), but these formations are poor in gold. Molybdenite occurs relatively rarely, although in individual instances it attains significant concentrations, becoming the leading component (Pil'ne Mine, Transbaykal region).

Feldspar, which sometimes imparts the character of pegmatite to a vein (Peshkovskiy deposit in Chita Oblast) is a significant component of individual deposits in a scheelite-quartz formation.

C. Scheelite-Skarn Formation

The scheelite-skarn formation possesses an entirely different composition of non-ore-bearing minerals, although the ore-bearing minerals remain the same as in the other two formations.

Scheelite and molybdenite may occur together in industrially useful quantities [Tyrnyauz, or Tyrny-Aus, Kabardinian ASSR]. Among other mineral ores, copper pyrite with sulfides of iron (Tuim, Khakass AO) or bismuth glance (Kumbel', Kirgiz SSR) are most often met. Besides, the sulfide combinations are usually later developments, as compared to the skarn minerals, scheelite is deposited later than the skarn minerals, but earlier than the sulfides.

Magnetite is a specific mineral ore of a few deposits of scheelite-skarn formation (Kashka-su, Central Asia). In addition, scheelite is often present in iron-bearing skarn deposits (Belaya Gora, Primorskiy Kray). Apparently, there is a continuous series of deposits, from iron-bearing skarn deposits containing scheelite to the scheelite-skarn deposits bearing magnetite, although the latter is comparatively rare. In addition to magnetite, hematite is found in these deposits.

The most characteristic minerals of the deposits under discussion are skarn mineral groups represented by calcium, magnesium and iron silicates, i.e., proxenes, garnets, amphiboles, vesuvianites and epidotes. Data exists showing the predominant development of scheelite in the so-called dark skarns, that is, skarns composed principally of minerals with high-iron content.

It should be noted that wolframite is rarely met in scheelite-skarn deposits and is completely absent in skarns which are rich in iron.

I. Occurrence of Tungsten Formations

Deposits of each of the three tungsten formations possess definite fields of occurrence within plicated zones of the Soviet Union.

There is a wolframite formation of especially wide development in Kazakhstan, where, in recent years, many deposits and manifestations of wolframite have been found. These include Akchatau, Degelen, Kzyltau, Akmaya, and other places.

In addition to Central Kazakhstan, there are known to be many wolframite deposits in the Kalba-Narymskiy Mountain Ranges in East Kazakhstan Oblast, (Chardoyak, Ubinskoye, etc.). Prospecting in recent years has shown the presence of this formation in Dzhungarskiy Alatau, in Alma Ata Oblast, (deposits of Agana-Katta, Dzhaman-Tass). Southward from Kazakhstan, it stretches into the western part of Tyan'-Shan' and the Talas and Chatkal River Basins of Kirgiz SSR) where the Toyalmysh, Dzhesho, Saragardon manifestations are.

Gornyy Altay is impregnated with deposits of a wolframite formation (Kolyvan', Kalguta, Chindagatuy, Belokurikha, Slyudyanka, Mul'chikha).

In Novosibirsk Oblast, probably at the extremity of one of the plicated curves of the Gornyy Altay, along the valley of the Ob River, the Kolyvan'-Obskoy cassiterite-wolframite deposit occurs which makes it possible to form a judgment concerning the presence here of a wolframite formation.

Deposits of wolframite occur in a large area and in great numbers in the Transbaykal Region. They are met from Dzhida in the west to Ol'doy in the east. Among them, many deposits have long been known, for example, Belukha, Bukuka, Antonova Mountain and Dul'durga (Chita Oblast).

Wolframite-cassiterite deposits have been developed also in Primorskiy and Khabarovsk Kray: in Iman there is the Kartunskoye deposit; at the headwaters of the Bureya River, a group of deposits at Ippata; and on the Lower Amur, the Bichi deposit.

Wolframite deposits occur on a small scale on the eastern declivity of the Urals (Boyevskaya group of deposits), in the area of the main Caucasus Mountain Range; and in infrequent manifestations in Ukrainian SSR. There are indications of the presence of wolframite formations at Chukot National Okrug.

The scheelite-quartz formation embraces large areas and, in general, follows the regions of gold deposits in its own development. Scheelite-gold-ore deposits have an appreciably greater prevalence than was formerly evident, although they are on a comparatively small scale.

The regional significance of the scheelite-quartz formation in the metallogeny of the Central or Southern Urals is becoming better known; however, the formation does not have industrial value. Beginning at Berezovsk, in which region there are quartz veins with scheelite, a belt of separate, small ore manifestations stretches in an uninterrupted chain as far as Mugodzhar.

Scheelite in the quartz veins of the Urals is known in the Chelyabinskiy Rayon (Shershneskaya group, Birgil'kinskoye deposit), and in a few veins in the Kochkap'skoye deposit. Further south is found the Gumbeiskiy scheelite district with the Buranovskiy, Balkanskiy and other deposits. Farther south, in the Southern Urals, there is the Aydrylinskaya group (Chkalov Oblast) or quartz-gold-ore deposits, containing scheelite on a small nonindustrial scale.

In the Northern Urals tungsten formations have been weakly developed.

The presence of scheelite in slicks, together with gold, has been established also in Timan, along the Usil'ma River (Komi ASSR).

Individual veins have been discovered in Karelo-Finnish SSR in the area of the Voitskiy mine.

Within the extent of the Caucasus Mountain Range there is a series of ore manifestations of a scheelite-quartz formation (on the greatest scale at Blyub' and Aksaut).

In the Northern Kazakhstan gold-bearing region, scheelite is present in a few veins of the deposits at Stepnyak and Bes-Tyube (Akmolinsk Oblast), but industrial concentrations have not as yet been met here, if the Barakonovski and a few other of the veins of the Pervomaiskiy Priiskiy Administration are not considered.

In the western part of Kazakhstan, from Imantavskiy Rayon to Dzhezkazgan (Karaganda Oblast) there are small spots of a scheelite-quartz formation (deposit at Baksa, veins of the regions Myk and Obly).

The presence of this formation in the region southwest of Lake Balkhash' may also be surmised, since scheelite and gold have been found together in the slicks in Botapak-Dala (Maybulak).

A scheelite-quartz formation, as a narrow strip containing deposits of industrial significance, is in evidence in the Kalbinskiy Rayon, to the southeast of the Kalbo-Narymskiy wolframite deposits (the gold-scheelite veins of the Kulundzhun and Manka mines).

Scheelite in gold-bearing quartz veins has been discovered also in Gornaya Shoriya (Tebechek deposits and others), at Salair in Kemerovo Oblast (Osinovskoye deposit), in the northern half of Kuznetskiy Alatau, the group of deposits of the Spasskiy Mt in Khakass AO, and in the majority of the gold ore deposits of Martayga (Berikul'), etc.

The scheelite-quartz formation proceeds from the northeastern part of Martayga to the southern Yenisey tayga region (Kuzeyevskoye deposit).

Wide occurrence of deposits of the formation under consideration has been established within the latitudinal gold-bearing plicated zone of the Zeya-Selemdzha basin (Amur Oblast) from the upper Kerbi River, through Kargino-Mynskiy Rayon, and the Un'ya-Bom River system in the Gilyuy basin; and, furthermore, in the placer districts of upper Amur. The Unglichikanskoye deposit and the Tretiy mine of Kharga (Amur Oblast) are the best known sites of the region.

To the west of the upper Amur district, a scheelite-quartz formation is sporadically evident in narrow strips along the northern and southern fringes of the area of development of the Transbaykal wolframite formation, the scheelite-quartz formation occasionally penetrating into individual parts of it. On the north are the Kazakovskoye, Peshkovskoye, and Bolyunskoye deposits (Chita Oblast) of the scheelite-quartz formation, and on the south the Eyrki-Davarn deposits in the middle course of the Onon River.

West of the Dzhida the wolframite formation in the Eastern Sayan region becomes a scheelite-quartz formation (scheelite in the gold-bearing slicks of Biryusinskiy Rayon).

The scheelite-quartz formation has a regional distribution, although characterized by weak intensity, in the Northern Baykal region, the Vitim-Olekma

Mesopotamia, at Malyy Khingan (Sutar in Jewish AO), in the central part of Sikhote-Alin (in the basin of Iman along the Yamutinze and Syau-Beyche Rivers), on the lower Amur River (in Udyl'skiy Rayon), at Dzhugdzhur (Kyutepskoye deposit); in the Kolyma gold-bearing region at Verkhoyan' [Verkh-yansk, Yakut ASSR?].

The scheelite-skarn formation is developed in comparatively small areas in the USSR, but is characterized by large-scale deposits. The Tyrnyauzskoye (Tyray-Aus Kabardinian ASSR) deposit in the northern Caucasus is one of these.

The scheelite-skarn formation has been especially widely developed in Central Asia, where some ten or more deposits are known. Many great deposits are located in the Nuratau mountain range: Ingichke, Lyangar, Koytash, Ugat. In the system of the Gissarskiy and Lavershanskiy Ranges (Tadzhik SSR), the following scheelite-skarn deposits occur; the Kara-Tyube, Kabuta, Maykhura and Takfon deposits, which are located farther east on the extension of these mountain ranges in the Alayskiy chain (Kaliksu and Kindyk deposits). With these should be associated also the Chorukh-Dayron deposit in the Mogoltau range, and the Kumbel-skoye and other deposits within the limits of Tyan'-Shan'.

The scheelite-skarn formation extends into the western portion of Eastern Sayan (Chibizhek, Balakhtisom deposits and other smaller manifestations). From here it proceeds into the southern portion of Kuznetskiy Alatau (Kemerovo Oblast), where there are known to be large quantities of skarn, copper and copper-iron ore deposits which contain scheelite. The Kiyalykh-Uzen'skoye, Glafirinskoye and Tuimskoye deposits are the most interesting of these.

Farther west, the scheelite-skarn formation appears in Gornaya Shorija in Altay Kray (Kechinskoye deposit), and to the south in the Chulyshmanskiy Mountains in Oirot AO (Atuur-Gol).

In the southeastern Transbaykal Region, in the Gazimur River basin (Chita Oblast), there is the Bystrinskoye deposit of scheelite, associated with copper and with iron-bearing skarns. In Primorskiy Kray the Ol'ga iron-bearing skarn deposits contain scheelite in small quantities (Belaya Gora).

An appreciable quantity of scheelite is observed in skarn of the Aldanskaya flagstone, associated with intrusive bodies of syenite-porphyry.

E. Causes of the Formation of Tungsten Deposits

The former notion that temperature and pressure differences were the reason for the formation, in some instances, of scheelite and, in others, of wolframite, may be regarded as inadequate. First, it contradicts the occurrence of both minerals together. Secondly, wolframite occurs both in pneumatolytic formations of the greisenite type (Sherlova Mt, Chita Oblast'), and in low-temperature deposits (Western US, Vaudler County) which indicates the wide range of temperature and pressure during the development of wolframite. Furthermore, scheelite is met also in high-temperature complexes, in pegmatites, skarns and in quartz veins, as well as with galenite and stibnite, the temperature of development of which must not be high.

Tungsten combines with calcium or with iron and manganese, depending primarily on the chemical content of the ore-bearing fluid.

Gannot's experiments (K.W. Gannot, Econ Geol, No 1, 1929) demonstrated the varied action of alkalis on scheelite and wolframite. The latter is rapidly disintegrated by alkalis, whereas they do not disintegrate the former. Accordingly, development of scheelite is only possible in an alkaline medium, but an acid or neutral medium is necessary for the development of wolframite.

For this reason the absence of wolframite in skarn formations, where there is an excess of alkali (calcium), thus becomes understandable. It also explains the fact that even when there is a large amount of iron in skarns, magnetite and scheelite are simultaneously developed, but not wolframite. A lack of manganese cannot be a reason for the absence of wolframite in iron-ore skarns. It is known that a few skarns (Ol'ga deposit of Primorskiy Kray) contain significant amounts of manganese, but scheelite is met in them right along with magnetite.

Topaz and fluorite are fairly frequent in wolframite deposits, demonstrating the presence of strong acid (fluorine) during the development of wolframite. Under these conditions the excess calcium combines with fluorine, and the tungstic acid combines with the weaker bases, iron and manganese. The presence of wolframite and scheelite in one ore body and the usually later development of scheelite permit us to surmise the replacement of the acidic medium by a neutral or even alkaline one.

The association of wolframite with acidic conditions is emphasized by the occurrence of wolframite deposits in the vicinity of leucocratic varieties of granite, alaskite, and aplite (Altay Transbaykal Region, Kazakhstan), the genetic connection of which with wolframite deposits has been convincingly shown. In turn, scheelite deposits usually occur in areas with rocks of the series quartz diorite-granodiorite (Amur Oblast, Eastern Sayan, Kuznetskiy Alatau, the Ural Mountains, Central Asia).

If one considers the gravimetric "klarki" of iron and calcium, it would seem that wolframite should be more widely distributed than scheelite. However, wolframite, especially in the group of countries of southeastern Asia (China, Burma), occurs in greater concentrations than scheelite. But scheelite has a wider regional distribution, at least in the USSR. This corresponds to the more frequent occurrence of quartz diorites and granodiorites as compared with leucocratic granites.

Thus the conclusion may be reached that, for ore encrustations containing tungsten, an alkali environment is the more usual. Only in the specific conditions of development of highly acidic granites is the growth of a wolframite formation possible.

Within the general conditions of the regional development of scheelites, special conditions are prerequisite to the emergence of scheelite-skarn formations, namely the presence of carbonaceous rocks.

F. General Conclusions

The specificity of the geological conditions of the regions of occurrence of the different tungsten formations demands a different mode of prospecting for tungsten deposits /in each region/.

Regions of growth scheelite-skarn formations very clearly conform (prirochemy k) to those regions where thick carbonate strata, broken by granodiorite intrusions, have a dominating significance. Among such are: the Nuratau, Gissar, Zerevshana, Alay, and Tyan--Shan' Mts in Central Asia; the western portion of Eastern Sayan; Tsentral'no-Aldanskiy Rayon. In addition, individual manifestations of a scheelite-skarn formation are observable in regions of local development of carbonate rocks, which are, however, intimately (udachno) united with intrusive bodies, for example, in the Caucasus (Tyrnyauz), in the Transbaykal Region (Bystrinskoye), and in Primorskiy Kray (Bolaya Gora).

The boundaries of areas of occurrence of a wolframite formation are very clearly outlined in regions with a limited portion of carbonated strata and with

a large development of high-acid granite intrusions. Among these are large areas of northeastern Kazakhstan with offshoots in Dzhungarskiy, Alatau, Kalba-Narymskiy mountain ranges and Gornaiy Altay, and the clearly defined belt in the Transbaykal Region, from Dzhida to the upper Amur region. These regions are practically bare of manifestations of scheelite mineralization.

The wolframite formation also accompanies leucocratic granite intrusions: those of Khabarovsk Kray (at the source of the Bureya River and in Udyl'skiy Rayon), and of the eastern declivity of the Urals (in the area of Boyevka).

However, in all instances when acidic phases of granite appear on a limited scale, along with rocks of a neutral composition, a wolframite formation is associated with scheelite mineralization, and complex deposits containing scheelite and wolframite result. This is well expressed in Primorskiy Kray (Iman), the Urals (Aydyrlaya), and in a number of deposits of the Transbaykal Region (Belukha, Bukuka).

The boundaries of a deposit of a scheelite-quartz formation are less clear, being joined by a link of two other formations. Furthermore, the conditions of development of this formation are not so narrowly restricted. Its appearance may be expected in various geological environments, with the exception of those favorable to the development of scheelite-skarn and wolframite formations i.e., those areas where numerous ultra-acidic intrusions or beds of carbonate rocks predominate.

These geological criteria permit one to select an area for prospecting correctly, and further to concentrate attention on deposits of one of the tungsten formations, which are characteristic of the given region.

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